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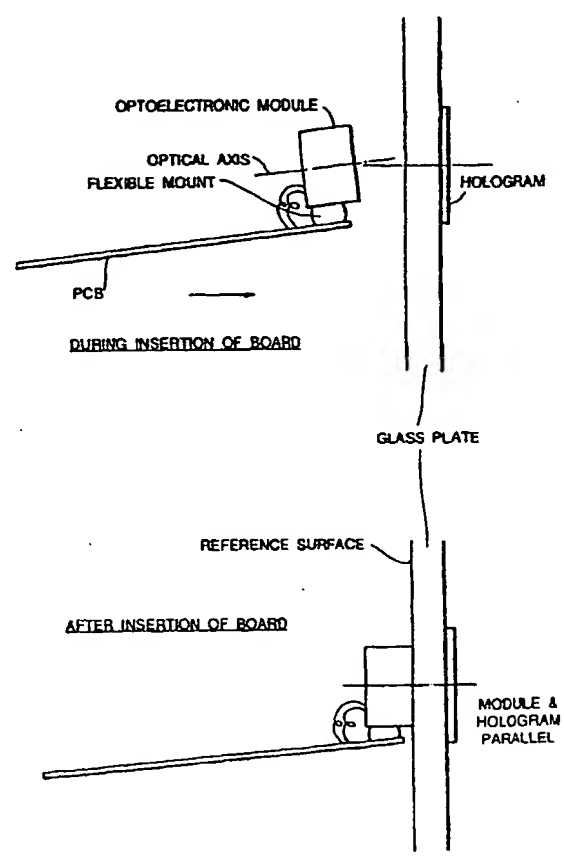
(54) Title: OPTICAL BACKPLANES

(57) Abstract

An optical backplane uses a pair of deflection holograms to route a signal from a transmitter to a receiver. The angular alignment of the transmitter is critical and the transmitter modules are flexibly mounted on component boards at right angles to the backplane so that the face of the transmitter contracts the backplane and is aligned correctly.



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OPTICAL BACKPLANES

The present invention relates to the implementation of optical backplanes using mass produced optical components and subsystems such as holograms and CD-type laser diodes.

According to the present invention there is provided a telecommunications optical backplane connecting system comprising a hologram mounted on a plane surface forming part of the backplane and an optical transmitter and/or a receiver having a plane front surface perpendicular to its or their optical axis and being flexibly mounted on a respective component board or boards, said board or boards being mounted perpendicular to the backplane so as to bring the transmitter and/or receiver front surface into mating contact with the plane surface of the backplane, or a further surface parallel thereto by flexing of the flexible mounting so as to bring the transmitter and/or receiver optical axis normal to the backplane.

The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 shows a schematic representation of a holographic backplane;

Figure 2 shows the geometry of the backplane of Figure 1;

Figure 3 shows graphically the relationship between lateral displacement and hologram deflection angle;

Figure 4 shows diagrammatically a self-aligning optical module;

Figure 5 illustrates a multi-bounce backplane configuration;

Figure 6 illustrates a typical layout of a rack of transmitter/receiver boards and

auxiliary reflectors/holograms;

Figures 7(a) to 7 (f) show examples of multiple-bounce interconnection paths;

Figure 8 illustrates the use of a combined holographic deflector/lens;

Figure 9 illustrates the effect of a collimated transmitter in the embodiment of Figure 8; and

Figure 10 illustrates the effect of a defocussed transmitter in the embodiment of Figure 8.

A schematic of a basic system is shown in Figure 1. A pair of deflection holograms route each signal to the desired location using a single reflection from a mirrored backplane. These holograms are simple linear gratings and their translational alignment with respect to the transmitters and receivers are not critical: any lateral movement in the transmitter will be mapped one-to-one at the receiver, thus the holograms need only be aligned to within ~1mm in order to achieve satisfactory performance (compare this with a guided interconnect system in which μm size tolerances are necessary). However one parameter which does need to be considered carefully is the angular misalignment of the transmitter. It will be shown below that this factor places a physical restraint on the dimensions and geometry of the backplane itself. Solutions are proposed which allow the full length of a 480mm (19") shelf to be interconnected.

With reference to Figure 2, consider the transmitter being angularly displaced by $\Delta\theta'$ to the normal of the deflection hologram. From Bragg's law, the change in angle, $\Delta\theta$, from the desired angle θ, is given by,

The dimensions of the backplane, viz. depth, t, and length, L, are related to θ by,

$$\tan\theta = \frac{L}{2t}$$

Differentiating with respect to θ gives

$$\frac{dL}{d\theta} = \frac{2t}{\cos^2\theta} \qquad (2)$$

Hence, from equations (1) and (2), an angular displacement of the transmitter of $\Delta\theta'$ results in a <u>lateral</u> beam displacement, ΔL, at the receiver of

$$\Delta L = \frac{2t}{\cos^3\theta}.\Delta\theta' = \frac{(L^2 + 4t^2)^{3/2}}{4t^2}\Delta\theta' \qquad (3)$$

This very strong dependence of lateral displacement on θ is illustrated in Figure 3 where ΔL is plotted against θ for a value of angular displacement of 0.1° and a backplane depth of 50mm. It can be seen that above θ ~ 50°, the value of ΔL begins to increase rapidly: if the latter is limited to 1mm then the maximum value θ can take is 56°, and the maximum interconnect length L is 150mm. In order to extend this interconnection length up to the width of a 480mm (19") shelf, it is proposed that one or more of the following three opto-mechanical solutions can be adopted: 1) the use of self-aligning optical modules, 2) the use of multiple reflections in dead space and 3) the use of deflector holograms incorporating lens-elements and a front hinging board mechanism.

This technique will limit the value which $\Delta\theta'$ can take and consequently permit greater interconnect lengths for a given backplane depth and lateral displacement.

In the optical backplane system, the holograms are fixed to a glass plate for

mechanical support, alignment and protection. The float glass plate used possesses very flat surfaces and is thus ideal as a reference for other optical components in the backplane. It is proposed that the transmit and receive optoelectronics are housed in light-weight, compact modules which are connected to the printed circuit boards (PCBs) by means of flexible mechanical mounts and electrical connectors, see Figure 4. They would be positioned along the back edge of the boards such that when the latter are inserted into the shelf the front faces of the modules come in contact with the glass plate and are automatically aligned parallel to the holograms irrespective of the angle at which the PCBs are positioned.

It was shown earlier that a single-reflection backplane allowed interconnection up to a length of 150mm. A multiple reflection technique, as illustrated in Figure 5, would allow one end of a 480mm (19") shelf to be interconnected to the other. However in order to maintain the superior flexibility of free space optical interconnects, it is important that these auxiliary reflections do not occur at the locations of intermediate receiver holograms, resulting in unacceptable crosstalk. It is therefore proposed to allocate the 'real-estate' between receiver holograms to particular transmitters and to use this dead-space to locate either simple plane reflectors or auxiliary holograms depending upon the relay function required. With reference to Figure 6, the backplane would be 'divided' into three sections. Communications within each individual section would be achieved using the standard one-bounce technique, with deflection angles always <56°. For links between adjacent sections, an auxiliary hologram would be used when L > 140mm. This device would redirect the light to the required receiver in the second section. For communications between the two end

sections an additional reflection would be employed before the redirecting hologram is addressed if L > 280mm. In the particular design illustrated, where adjacent boards are separated by 20mm, the first reflector/hologram is located $7^1/_3$ board pitches away from the transmitter and the second device $14^2/_3$ pitches away.

A selection of various interconnect paths are shown in figures 7(a) to 7(f).

Figure 7(a) shows a single reflection interconnection within a single one of the sections shown in Figure 6.

Figures 7(b) and 7(c) show two examples of interconnection between adjacent sections using an auxiliary hologram.

Figure 7(d) shows interconnection between the end sections using an auxiliary hologram.

Figure 7(e) shows interconnection between the end sections using an auxiliary reflector and a second hologram.

Figure 7(f) shows an interconnection network exploiting the fan-out capabilities of auxiliary holograms.

The final example shown in Figure 7(f) illustrates how each auxiliary hologram can provide a fan-out capability thus enhancing the flexibility of the system without putting undue strain on any individual holographic element.

One of the prime benefits of employing holograms as the deflecting elements is their capability to incorporate other optical functions, such as lensing. A holographic optical element (HOE) could thus be used not only to deflect the transmitter beam but in addition to <u>image</u> the source onto the receiver, thus minimising the extent of lateral misplacement of the beam at the receiver due to shifts in the position of the

transmitter, see Figure 8. In order to optimise the demagnification factor, D, of any transmitter misalignment, the transmitter/lens distance, U, must be maximised with respect to the lens/receiver, distance, V, since

$$D = \frac{U}{V} \qquad (4)$$

If the transmitter produces a collimated beam, then the use of a holographic lens whose focal length equals V, results in a value of $D = \infty$ ie. the system is totally immune to lateral displacements of the transmitter, see Figure 9. It would however now be particularly sensitive to any residual angular misalignment of the transmitter. A more beneficial situation would be to slightly defocus the collimation of the transmitter such that the source appeared to emanate from a position at the front edge of the board, and to locate the board locking (and consequent hinging) mechanism at this same location, so that any angular misalignment of the board was centred on the apparent source position, see Figure 10.

The optimal solution will depend upon the relative magnitudes of the boards potential angular and lateral misalignment. In cases where the former is greater than the latter, the defocussed condition described above should be chosen; in cases where the situation is reversed, the transmitter should be more collimated.

CLAIMS

1. A telecommunications optical backplane connecting system comprising a hologram mounted on a plane surface forming part of the backplane and an optical transmitter and/or a receiver having a plane front surface perpendicular to its or their optical axis and being flexibly mounted on a respective component board or boards, said board or boards being mounted perpendicular to the backplane so as to bring the transmitter and/or receiver front surface into mating contact with the plane surface of the backplane, or a further surface parallel thereto by flexing of the flexible mounting so as to bring the transmitter and/or receiver optical axis normal to the backplane.

2. A telecommunications optical backplane as claimed in claim 1, further comprising an auxiliary hologram providing multiple reflections.

3. A telecommunications optical backplane as claimed in claim 1 or 2, wherein the deflection angle is less than 56°.

4. A telecommunications optical backplane as claimed in claim 1, 2 or 3 wherein the hologram comprises a holographic deflector/lens.

5. A telecommunications optical backplane as claimed in claim 4 wherein the holographic deflector/lens is arranged to provide a defocussed image of the transmitter at the receiver.

6. A telecommunications optical backplane as claimed in claim 5, wherein the component board has a locking/hinging point at the apparent transmitter position.

Fig.1

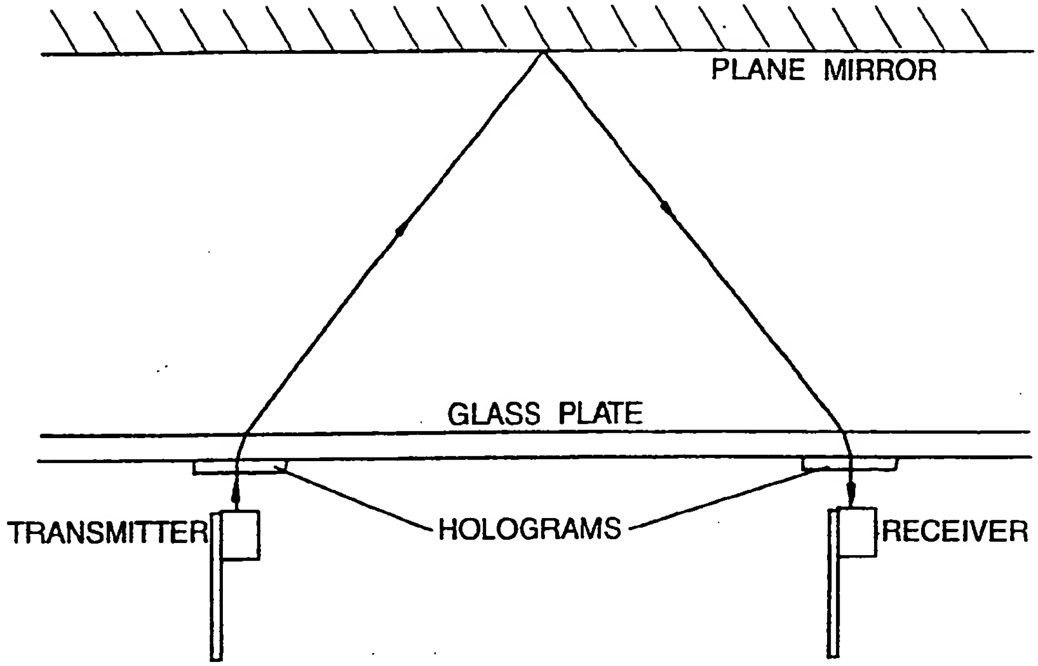

PLANE MIRROR
GLASS PLATE
TRANSMITTER
HOLOGRAMS
RECEIVER

Fig.2

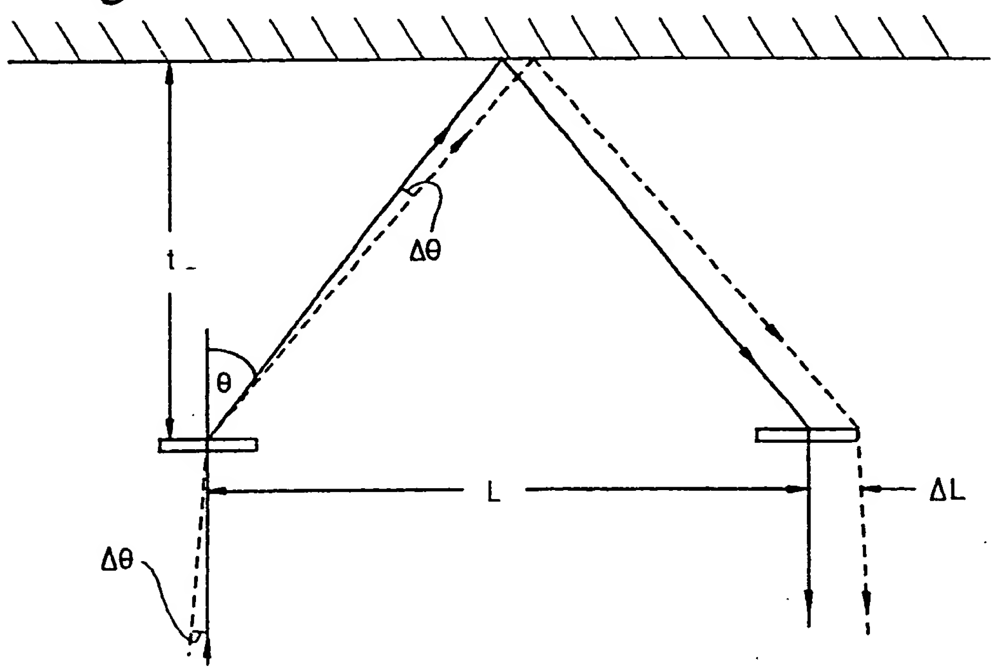

t
Δθ
θ
L
ΔL
Δθ

Fig.3

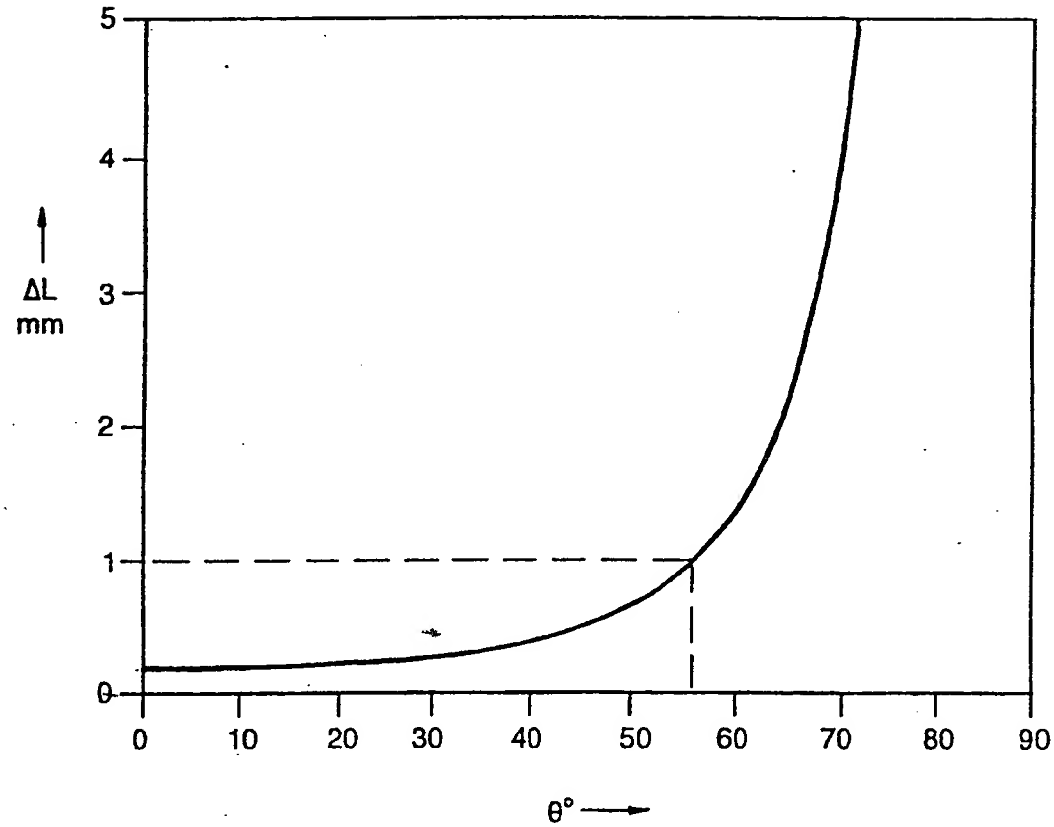
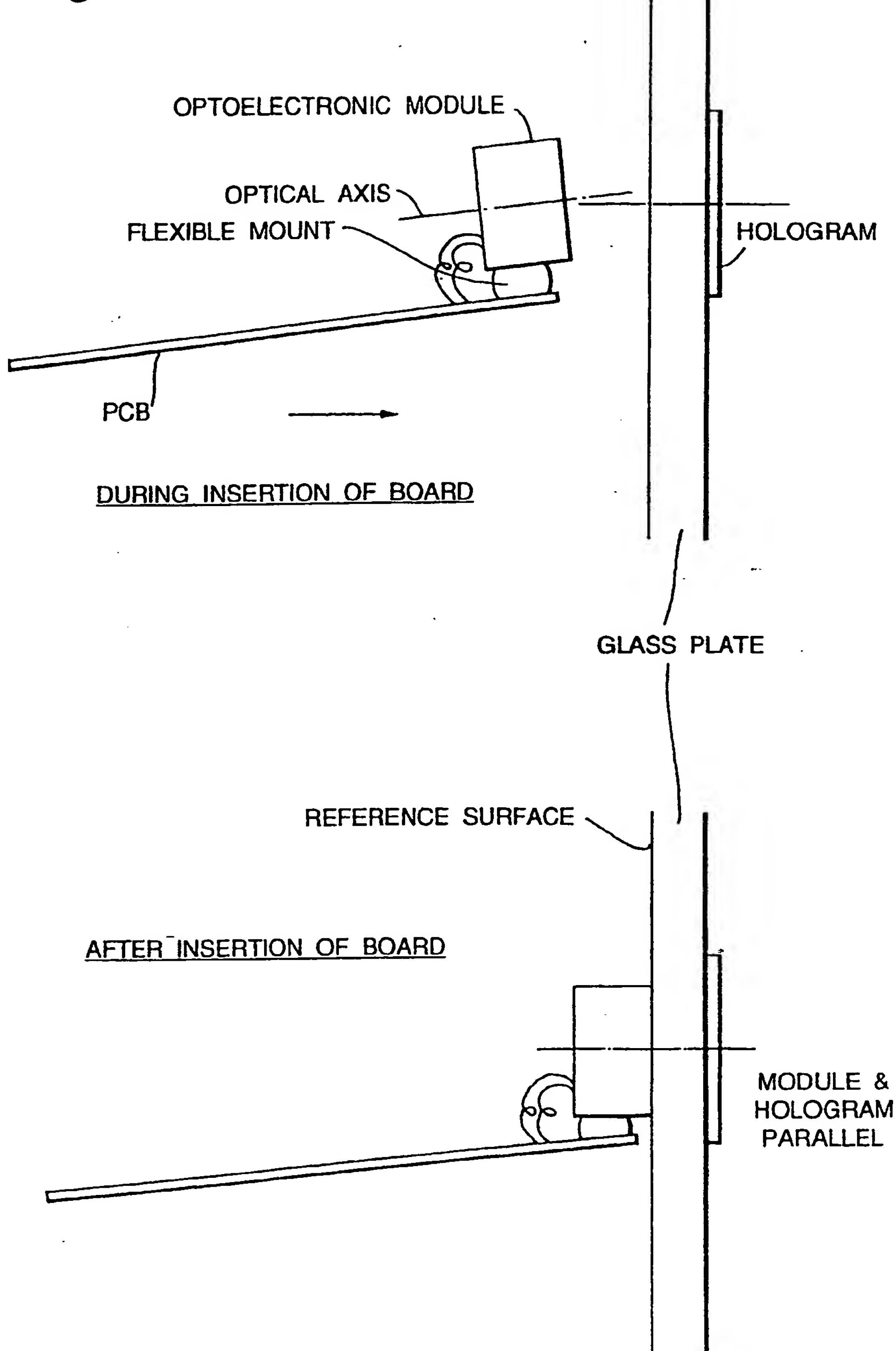


Fig.4


OPTOELECTRONIC MODULE
OPTICAL AXIS
FLEXIBLE MOUNT
HOLOGRAM
PCB
DURING INSERTION OF BOARD
GLASS PLATE
REFERENCE SURFACE
AFTER INSERTION OF BOARD
MODULE & HOLOGRAM PARALLEL

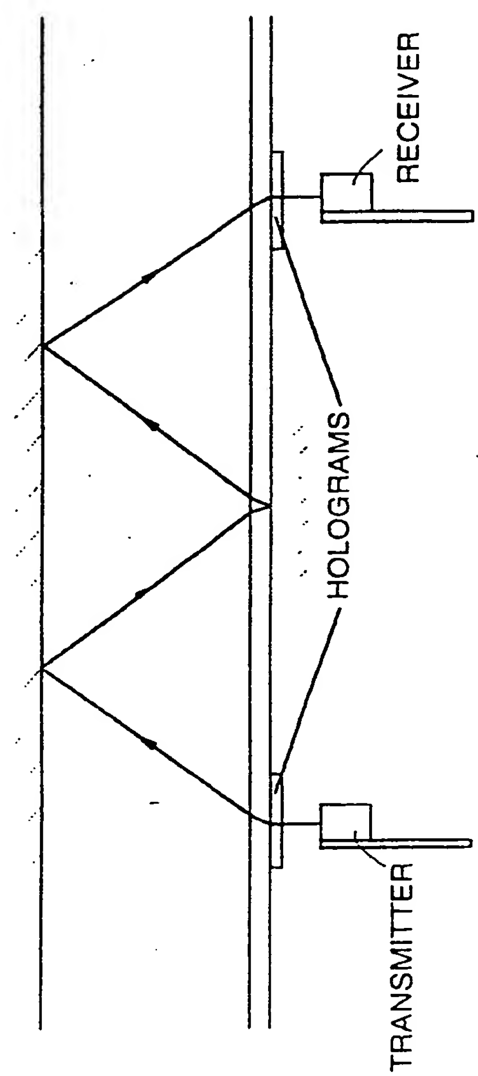

RECEIVER
HOLOGRAMS
TRANSMITTER

Fig.5

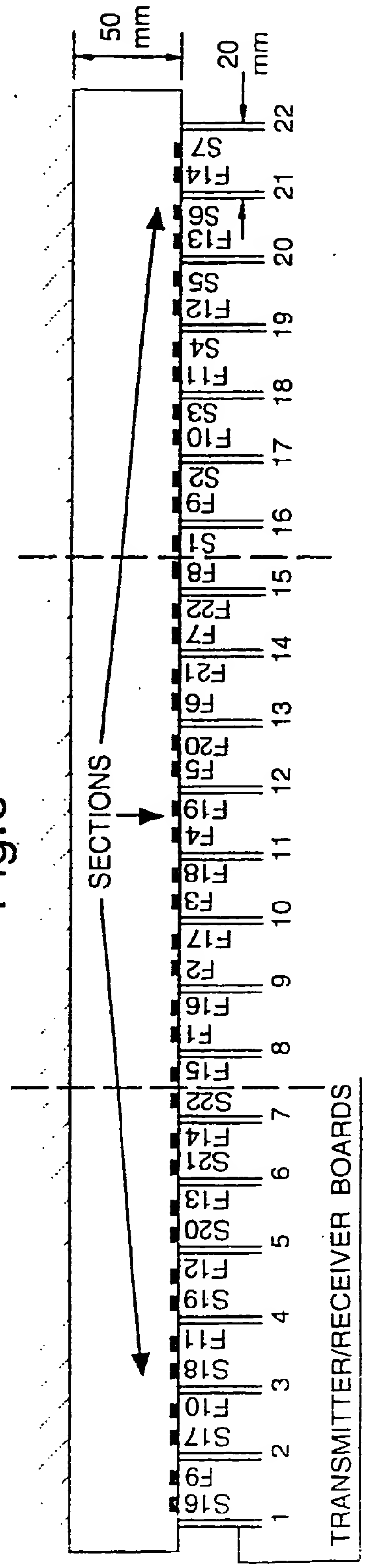

50 mm
20 mm
SECTIONS
TRANSMITTER/RECEIVER BOARDS
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
S16 F9 S17 F10 S18 F11 S19 F12 S20 F13 S21 F14 S22 F15 F1 F16 F2 F17 F3 F18 F4 F19 F5 F20 F6 F21 F7 F22 F8 S1 F9 S2 F10 S3 F11 S4 F12 S5 F13 S6 F14 S7

Fig.6

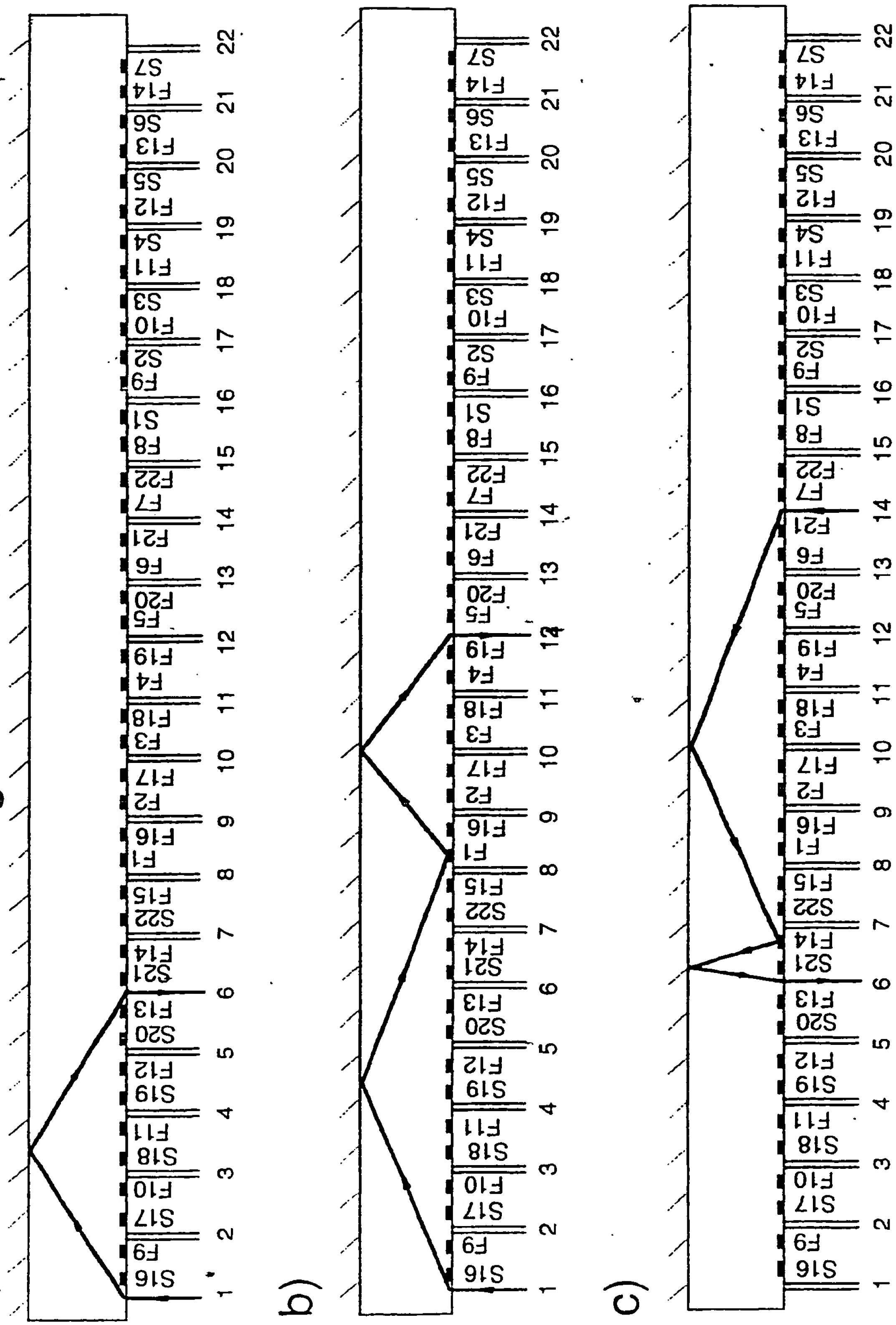


Fig.7

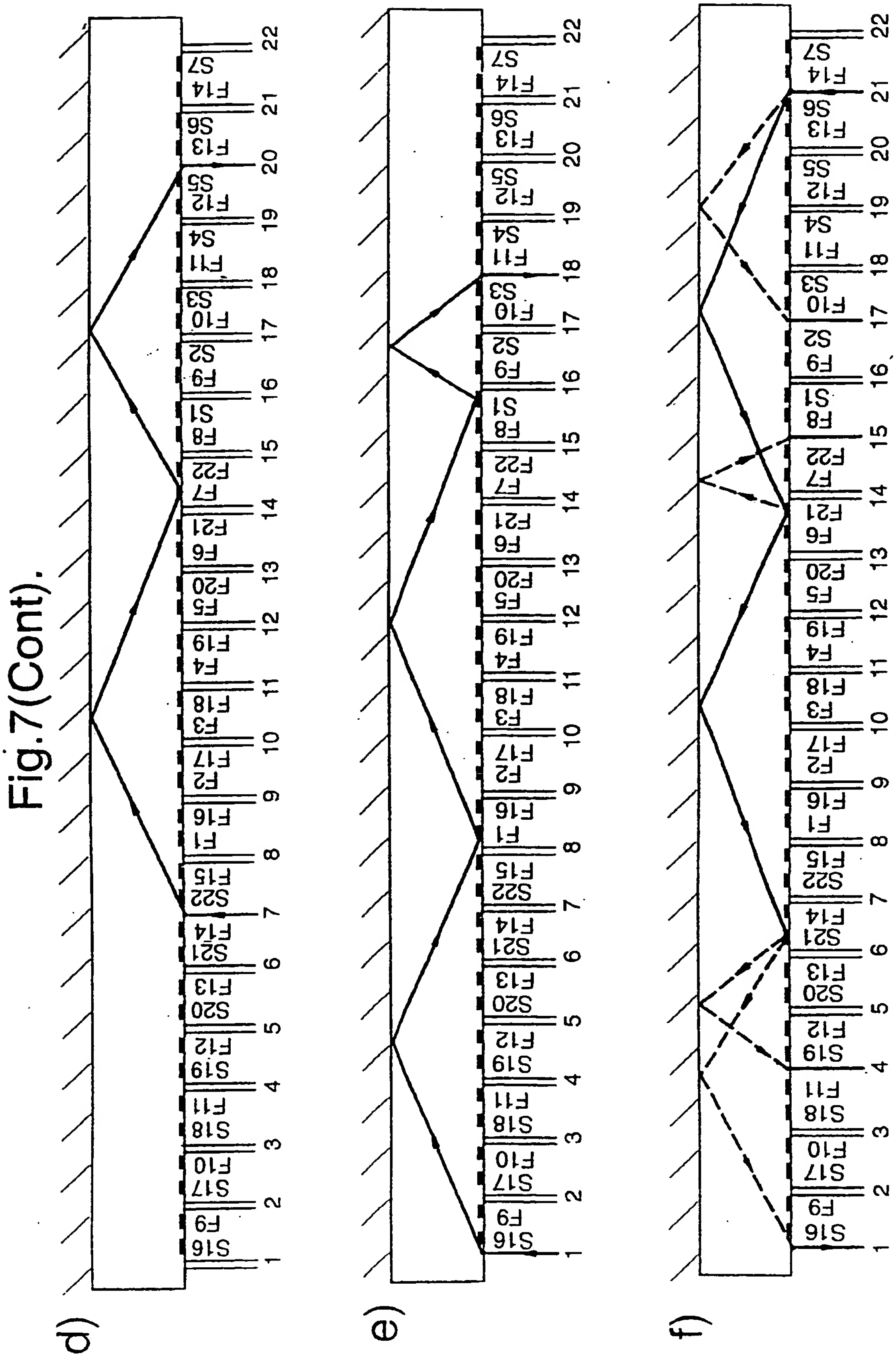


Fig.7(Cont).

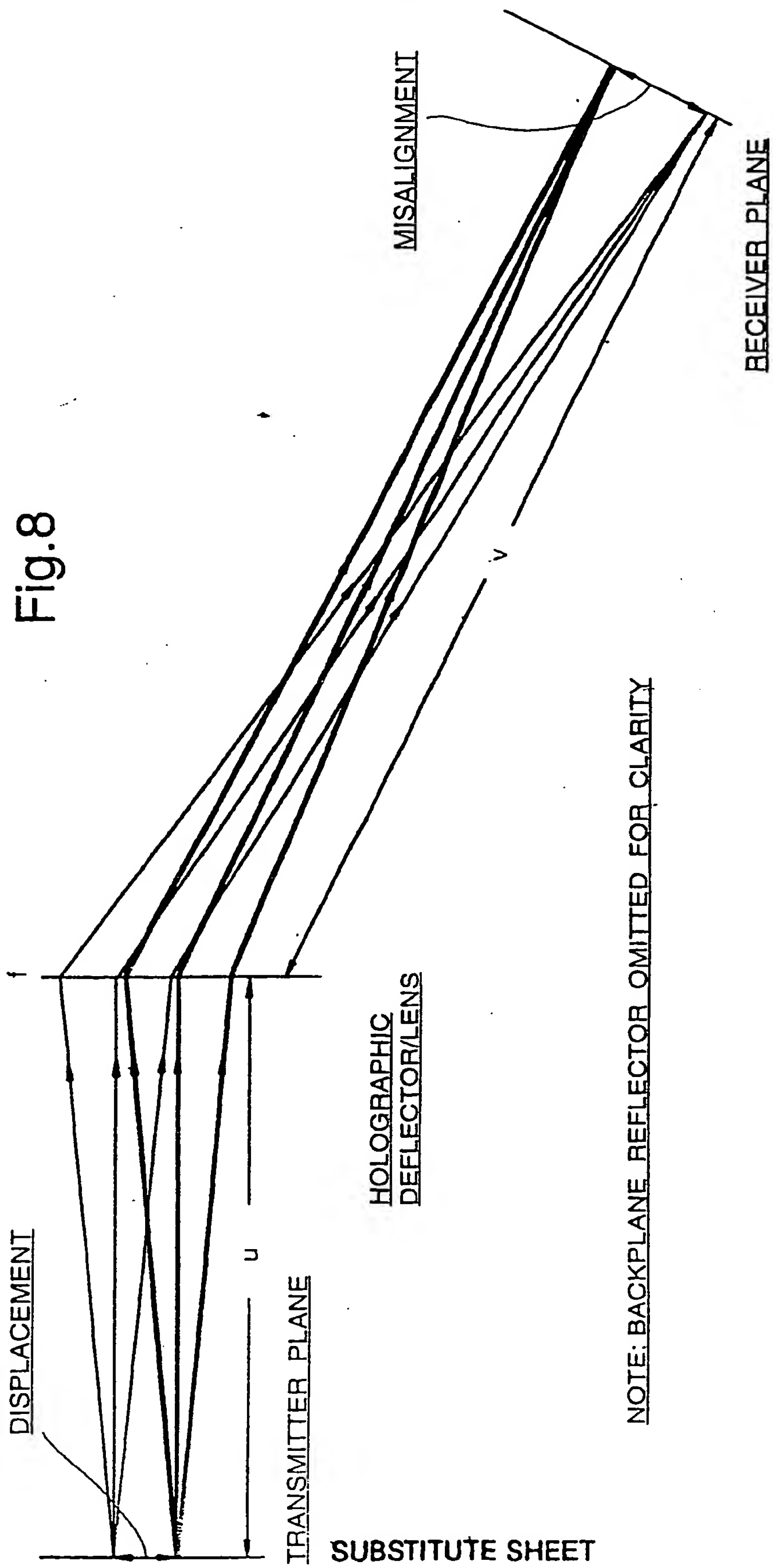

MISALIGNMENT
RECEIVER PLANE
v
HOLOGRAPHIC
DEFLECTOR/LENS
NOTE: BACKPLANE REFLECTOR OMITTED FOR CLARITY
DISPLACEMENT
u
TRANSMITTER PLANE

Fig.8

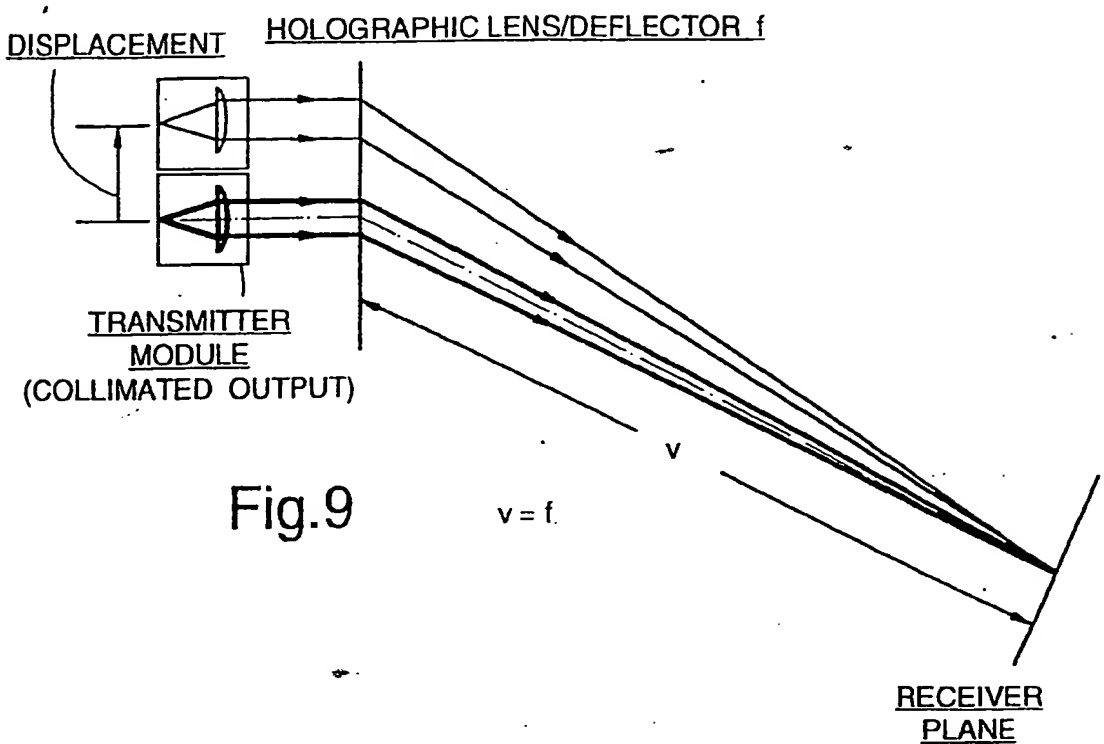

DISPLACEMENT
HOLOGRAPHIC LENS/DEFLECTOR f
TRANSMITTER
MODULE
(COLLIMATED OUTPUT)
v
v = f
RECEIVER
PLANE

Fig.9

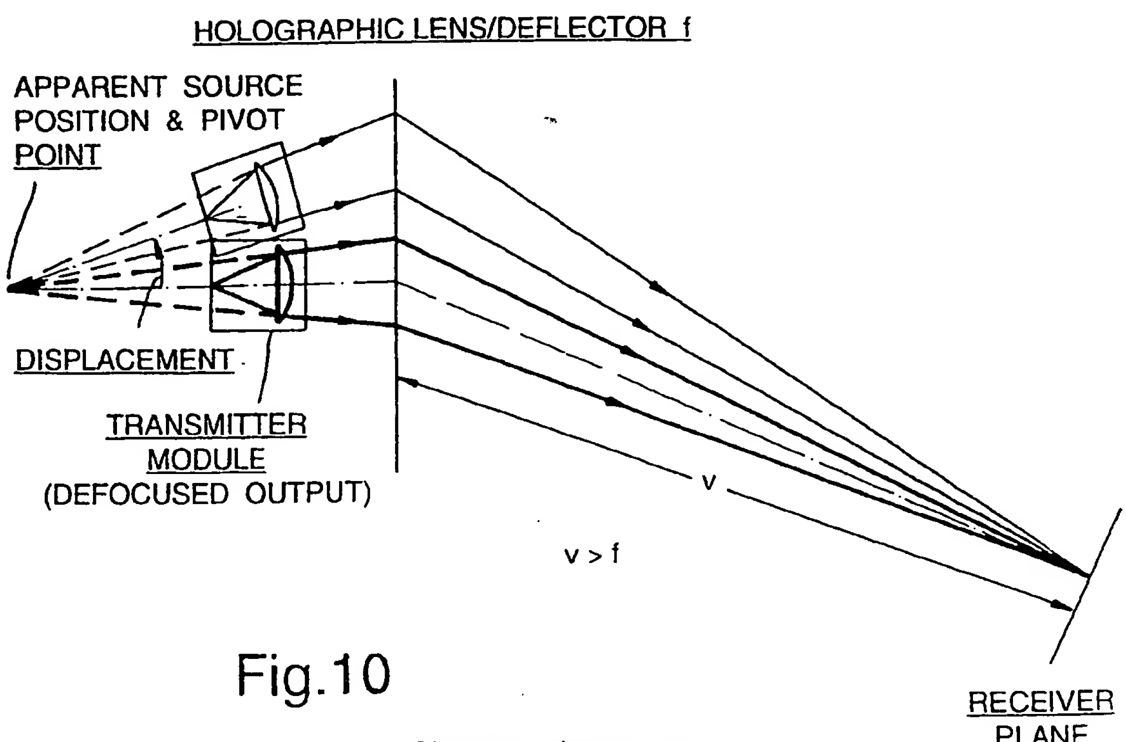

HOLOGRAPHIC LENS/DEFLECTOR f
APPARENT SOURCE
POSITION & PIVOT
POINT
DISPLACEMENT
TRANSMITTER
MODULE
(DEFOCUSED OUTPUT)
v
v > f
RECEIVER
PLANE

Fig.10

International Application No
PCT/GB 94/00220

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 G02B6/42 G02B5/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	APPLIED OPTICS, vol.27, no.20, 15 October 1988 pages 4251 - 4254 K.H.BRENNER 'diffractive-reflective optical interconnects' cited in the application ---	1
A	JOURN. OF LIGHTWAVE TECHNOLOGY, vol.9, no.12, 1 December 1991 pages 1650 - 1656, XP000275432 R.C.KIM 'an optical holographic backplane interconnect system' cited in the application ---	1
A	DE,A,39 32 652 (SIEMENS) 11 April 1991 see claims; figures ---	1

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
29 April 1994	4.05.94

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,4 720 634 (L.D.AURIA) 19 January 1988 see claims; figures ---	1
A	EP,A,0 486 208 (GPT) 20 May 1992 see claims; figures ---	1
X,P	WO,A,93 09456 (UNIVERSITY NORTH CAROLINA) 13 May 1993 see claims; figures ---	1-3
A,P	EP,A,0 560 511 (ATT) 15 September 1993 see claims; figures -----	1,4,5

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 94/00220

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
DE-A-3932652	11-04-91	NONE		
US-A-4720634	19-01-88	FR-A-	2590995	05-06-87
		EP-A,B	0196933	08-10-86
		JP-A-	61196210	30-08-86
EP-A-0486208	20-05-92	CN-A-	1063172	29-07-92
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		JP-A-	4286191	12-10-92
		PT-A-	99510	31-12-93
		US-A-	5182780	26-01-93
WO-A-9309456	13-05-93	US-A-	5237434	17-08-93
		AU-A-	3060192	07-06-93
EP-A-0560511	15-09-93	JP-A-	6011666	21-01-94